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Skim Reading by Satisficing: Evidence from Eye Tracking

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ABSTRACT

Readers on the Web often skim through text to cope with the volume of available information. In a previous study [11] readers' eye movements were tracked as they skimmed through expository text under time pressure. This article presents novel analyses of these eye-movement data. Results indicated that readers were able to explicitly direct attention to the most important information in the text and that this improved performance on a subsequent test of memory for the meaning of text. We suggest readers achieve this by *satisficing* – reading through text until the rate of information gain drops below threshold and then skipping to the next section of text. Further analyses of gaze patterns for paragraphs and pages supported this explanation. Combining satisficing with some form of scanning or sampling behaviour could explain patterns of reading found on the Web. A greater understanding of the way that text is read on the Web would assist many producers of online content.

Author Keywords

Skimming, reading, speed reading, information foraging, time allocation.

ACM Classification Keywords

H5.4. Information interfaces and presentation (e.g., HCI): Hypertext/Hypermedia.

INTRODUCTION

One of the most important and widespread interactions between humans and computers is the reading of text online. Descriptive studies suggest that there are a number of ways that reading on the Web differs from other forms of reading but one of particular importance is the tendency for online readers to *skim* text. Because of the sheer volume of text on the Web, and its interlinked and searchable nature, the amount of easily accessible information often outstrips the time available to read it. To compensate for this, it is

commonplace to employ some form of rapid, selective reading strategy such as omitting words, paragraphs or pages [1,19,21]. Presumably, the purpose of such skimming is to maximise the information gained by focusing on the most useful sections of text.

Background Literature

Until recently the literature on text skimming provided limited support for the idea that, when there was insufficient time to read all the text available, readers could effectively focus on the most important parts of the text. Masson [20] varied the duration for which texts were presented to participants and then tested recognition performance for important and unimportant sentences from the texts. As reading rate increased, scores on the recognition test deteriorated roughly equally for important and unimportant information. Similarly, other studies [5,12,18] found that the comprehension of important and unimportant information from a text was equally degraded by an increase in reading rate. Thus, it is unclear from this work whether skimmers really can improve their understanding of the most important elements of a text by skipping over less important sections of text.

One limitation of these studies of skimming was the length of the texts used – typically around 500 words. To effectively focus on more important sections of text, the reader must be able to make inferences about the content of parts of the text before they are read (so as to know whether to skip over them). Assumptions of continuity and coherence may allow such inferences, but these processes may be more effective for larger amounts of text – as are found on the Web. In previous work [11] we have tested this suggestion by presenting readers with texts of over 3000 words for a constrained amount of time and comparing skimming with linear reading at normal pace. Because both conditions had the same amount of reading time, this design tested the *improvement* in understanding that could be attained through skimming unlike the other studies of skimming that tested the *decrease* in understanding due to a reduction in reading time. Moreover, this design was more representative of the typical situation on the Web where readers have a limited amount of time and must decide to either read a smaller section of text at normal pace or skim a larger section of text.

After reading, participants in [11] were tested on their understanding of the text in the same way as in [20].

Important and unimportant sentences from the text were presented one at a time to participants. Some of the sentences had their wording changed so as to contradict their original meaning and participants had to categorise each sentence as either consistent or inconsistent with the text. [11] found that memory for the meaning of the important sentences was better in the skimming condition than in the control condition in which some of the text was read through at normal speed. There was no difference in memory for the unimportant sentences. This result was found for pages structured linearly and for a hierarchical Website-like arrangement of pages.

To our knowledge [11] is the first empirical demonstration that skimming can improve readers' understanding of important information given a fixed budget of time. However, the advantage of skimming was not apparent when compared with conditions in which linear readers read half of every paragraph [11]. This raises the possibility that skimming is effective primarily because it distributes attention across a document. Important information plays a major role in the macrostructure of a text [17] and thus may often be inferable from neighbouring sections. For example, reading any text within a section on the medical applications of hypnosis could be a useful clinical technique. This account is quite different to the suggestion that skimmers are able to deliberately direct attention to important parts of the text.

Extensions to Eye tracking Analyses

These alternatives are tested for the first time by analysing gaze location and duration, recorded by tracking eye-movements during skim reading. This approach enables us to test directly the extent to which skimmers focused on the most important text and skipped over text that was less important. Understanding the effectiveness with which skimmers can focus on the most important elements of a text has clear practical relevance as it can guide writers as to the proportion of a text that should contain important information and also the extent to which this information needs to be signposted using headings or other highlighting tools.

The second purpose of the analyses of eye-tracking data that are presented here is to examine the process of skim-reading and contribute to the development of an account of the way that skimmers manage their time allocation whilst reading. This goal has even greater applicability, as an understanding of *how* users choose which text to skip over can facilitate the creation of text and Websites that specifically cater for the methods of readers with limited time. The importance of this topic has already been recognised by Nielsen who has argued that text online is read differently to text elsewhere and that writers should take account of these differences [21].

Skim Reading Strategies

An important feature of Nielsen's description of online reading is that it is sensitive to the limitations in time to read material on the Web. Observations of eye-movements

while browsing the Web have led him to conclude that readers typically scan web pages in an "F-shape" [22]. That is, a horizontal movement is made along the top of the page, followed by another horizontal movement of shorter length further down the page and then finally a vertical scanning movement down the left side of the page. Reading text in an F-shape is one potential method that skim readers could use to allocate their time. This strategy provides an easily executable technique for sampling a portion of text from a page before moving to a different page.

Another strategy for allocating time across a text is to use a strategy identified by Reader and Payne [28], that they termed *satisficing* (see also [30]). The description of this strategy is derived from an information foraging approach to browsing [24] in that it assumes that readers are sensitive to some proxy for "information gain" and use this as a basis for their behaviour. When satisficing, readers set a threshold of satisfaction and linearly read through a unit of text as long as the rate of information gain remains above this threshold. When a unit of text has been read or current satisfaction drops below threshold readers move to the next unit of text. During skimming it might be expected that the satisficing threshold be rather high, meaning that the threshold was often unmet. The theory does not specify the size of the unit of text that readers evaluate, however, data from [28] and [11] suggest that the paragraph may be an appropriate unit of text, not least because it is the most perceptually salient unit of text that is smaller than a page.

Some support for satisficing was found by [11]. They reported that skim-readers spent more time reading the first half of each paragraph, presumably because when the rate of information gain was low, participants skipped over the second half of the paragraph and started the next paragraph. [11] also reported that skimmers spent more time reading paragraphs that were earlier in a page. This indicates that they may have been evaluating the page as a unit of text as well as the paragraph. Judging (and deciding whether to abandon) units of text at more than one level complicates the account of satisficing but seems plausible – when a paragraph is judged uninformative perhaps the page or Website that contains the paragraph are also being judged as uninformative.

These results were derived from eye-tracking data from the participants in Experiment 2 from [11]. Here we report more in depth, finer grained analyses of this data that allow new hypotheses to be tested. All of the analyses reported in this paper are novel and were not included in [11].

To test whether participants focused on the most important text while skimming we compare total gaze duration for the important and unimportant sentences from the test of memory for meaning. These sentences were classified as important or unimportant by a separate group of participants. We predict that important sentences should be more likely to be read than unimportant sentences. However, with units of text as small as a sentence, given a

font-size that was chosen with ecological validity in mind more than eye-tracking accuracy, there is a danger of fixation measures made noisy by eye-tracker error. Such noise is not confounded with our hypothesis, but it necessarily weakens the test. Consequently, we also consider the larger units of text – line and paragraph – that embed important versus unimportant sentences. Fixation measures of such larger units will be less affected by eye-tracker error. Furthermore, within well-written text, consecutive sentences will deliberately contain shared referents to improve coherence [31] meaning that the information surrounding an important sentence should also be more likely to contain important information. Thus, we predict that lines and paragraphs that contain important sentences should also be more likely to be read than lines and paragraphs containing unimportant sentences.

A further test of the extent to which actually reading text produced any improvements in understanding is to compare sentences that were answered correctly and incorrectly during the test of memory for meaning that followed skim-reading. We predict that gaze duration during skimming should be longer for sentences that were answered correctly than for sentences answered incorrectly.

The eye-tracking analyses reported in [11] do not clearly decide between Nielsen's description of F-shaped browsing and satisficing. The two horizontal movements across the page described by Nielsen could produce the increased reading time for the first half of a paragraph relative to the second half of a paragraph. Here though, we test reading time for each individual line within a paragraph. If readers make a simple horizontal movement then scan down the page, reading times for each line within a paragraph should decrease in a step function. In comparison, satisficing predicts that reading time per line, averaged over a group of readers or a set of paragraphs, should decrease over the course of a paragraph but this decrease should be gradual as the rate of information gain will decrease at different rates for different paragraphs. Indeed, where important information is contained within a paragraph, readers may read all of a paragraph. We also test the extent to which skim-readers scan down the left hand side of the page by measuring gaze duration in vertical stripes across the width of the page.

METHOD

Participants

Participants were 10 male and 18 female students from the University of Manchester. The mean age was 20.93 years ($SD = 2.24$). These were all the participants that were successfully eye tracked in Experiment 2 from [11] – data for the remaining 4 participants from that experiment could not be used due to technical difficulties in achieving accurate calibration.

Apparatus

A Tobii 1750 binocular eyetracker monitored participants' eye movements while they read. The eyetracker consisted

of a high-resolution camera embedded in a 17-inch monitor. A PC was connected to the eyetracker and the stimulus materials were presented on the eyetracker monitor. The fixed wide-angle camera allowed data to be recorded from a freely moving person with approximately 20 cm of freedom on each side. The screen resolution on the monitor was set to 1024 x 768 pixels and the sampling rate was 20 ms. Participants were seated 61 cm from the monitor.

The application ClearView was used to export the eye-tracking data. The fixation filter from this package determined the start and end of a fixation. Thus, a fixation was deemed to start when the distance between each successive gaze point remained within a specified number of pixels for a specified period of time. A fixation ended when the distance between successive gaze points exceeded the threshold. The fixation filter size was set to 40 pixels and the minimal fixation duration was 80 ms. Analyses were conducted on "Total Gaze Time" which was the sum of all fixation durations in a region regardless of order.

Materials

Two texts were adapted from Scientific American articles on Hypnosis (3134 words) and Attention-Deficit Hyperactivity Disorder (3252 words). The two texts were restructured into 11 pages of approximately equal length (Page length in words: ADHD, $M = 292.64$, $SD = 75.42$; Hypnosis, $M = 281.73$, $SD = 87.20$). Page boundaries were selected so that the content within each page addressed a distinct topic that could be summarised using a single heading. A separate heading was devised for each page. There were 30 paragraphs in the ADHD text and 28 paragraphs in the Hypnosis text

From each text, 36 target sentences were selected for the test of readers' memory for meaning. These sentences were categorised following a procedure used in [20]. A group of 20 undergraduates who did not participate in the main study rated the sentences for their importance to the general meaning of the text. The 18 most highly rated sentences were used as the "important" sentences and the 18 lowest rated sentences were used as the "unimportant" sentences. For the test of memory for meaning, half of the important sentences and half of the unimportant sentences had their meaning changed so as to be semantically incongruent with the original statement. Because results from the memory for meaning are not analysed here, we shall not distinguish between sentences that did or didn't have their meaning changed during the test of memory for meaning.

The different sentence types were distributed approximately evenly across the different pages in the text with all pages containing at least one target sentence. The standard deviation of the number of sentences per page was 1.39. The mean number of words between the start of the text and the target sentence was 1467 ($SD = 958$) for the important sentences and 1571 ($SD = 898$) for the unimportant sentences. This difference was not significant ($t < 1$).

Across both texts there were 36 important sentences and 36 unimportant sentences, these were distributed so that in

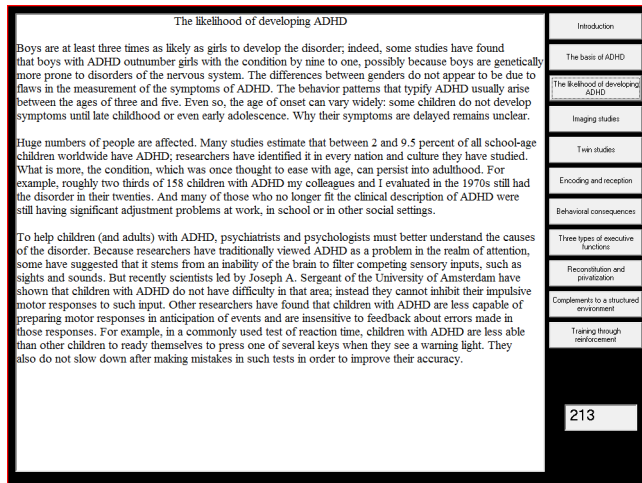


Figure 1. Screenshot showing the presentation of the texts.

total in the first half of a text there were 21 important sentences and 19 unimportant sentences.

Important and unimportant sentences were approximately evenly distributed across paragraphs (standard deviation of number of target sentences per paragraph = .80). Target sentences were equally distributed across both halves of a paragraph within both texts. Thus, across both texts there were 18 important sentences and 18 unimportant sentences in the first half of a paragraph and the same number in the second half of a paragraph.

A purpose-built program presented the texts and the subsequent test of memory for meaning. The texts were presented one page at a time in a large box that filled most of the screen (see Figure 1 for a screenshot). Participants could navigate back and forth through the text by clicking on one of 11 buttons from a column down the right hand side of the screen (top to bottom in page order). Each button was labelled with the heading from the corresponding page. The texts were presented in font size 12, with up to 106 characters fitting on each line. Text was single line spaced and there was an empty line of text between paragraphs. In the bottom right hand corner of the screen a clock counted down the remaining number of seconds before the text was removed.

Procedure

Participants were instructed that they would be presented with a text on either Hypnosis or ADHD for a limited period of time before being tested on their understanding of the whole text. They were also told that there was not enough time to read through the text at normal reading speed but that they should allocate their time while reading so as to maximise performance on the subsequent test of memory for meaning. The ADHD text was presented for

325 seconds and the Hypnosis text was presented for 313 seconds which meant participants would have to read at 600 words per minute to read through the complete text (normal reading speed is approximately 225 words/minute – [20]).

When the time for reading had elapsed participants were required to complete the test of memory for meaning. Target sentences were presented serially in the centre of the screen in a randomised order. Participants categorised each sentence as either consistent or inconsistent with the text they had just read.

RESULTS

Reading Times for Important and Unimportant Text

The time spent looking at the target sentences, the lines containing the target sentences and the paragraphs containing the target sentences are given in Table 1. These total gaze times are given per character to aid comparison across sections of text that differ in length. (Total time spent fixating on an area of text was measured and then divided by the maximum number of characters that could have fitted into the area.) Means were calculated first within participants and then between participants. All means and standard deviations reported in this article reflect the average of the individual means across all 28 participants. All times were log transformed before analysis, although this made no difference to the pattern of significance. (See [26] for justification of the use of transformations upon latencies.)

Table 1 indicates that important sentences were read for longer than unimportant sentences, $t(27) = 4.52, p < .001, d = .55$. This effect was replicated when the areas of text that contained important and unimportant sentences were compared. Thus, lines that contained important sentences were read for longer than lines that contained unimportant sentences, $t(27) = 4.99, p < .001, d = .59$, and paragraphs

	Important Sentences		Unimportant Sentences	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Sentences	13.26	6.98	8.95	3.98
Lines containing sentence	10.12	4.58	6.76	2.84
Paragraphs containing sentence	9.60	3.94	6.76	3.33
Correct sentences	16.86	11.35	10.51	5.63
Incorrect sentences	9.20	4.76	7.27	4.69
Proportion correct	.73	.13	.66	.12

Table 1. Total gaze time per character (ms) for target sentences and for lines and paragraphs that contain target sentences. Target sentences are either important or unimportant sentences from the text. Target sentence total gaze times per character also provided split according to whether the target sentence was correctly or incorrectly

categorised during the test of memory for meaning. Final row includes proportion of important and unimportant sentences correctly categorised in test of memory for meaning from [11].

that contained important sentences were read for longer than paragraphs that contained unimportant sentences, $t(27) = 3.92$, $p = .001$, $d = .57$. (Paragraphs that contained both sentence types are excluded from the means in Table 1 and these analyses.)

Reading Times for Correctly and Incorrectly Remembered Text

The second goal for this study was to test whether memory for the meaning of a sentence was related to the time spent looking at the sentence. For each participant, target sentences were categorised as correct or incorrect according to performance on the test of memory for meaning. For the purposes of comparison, the proportion of important and unimportant sentences correctly classified on the memory for meaning test from [11], are reproduced in Table 1. Total gaze times per character for sentences answered correctly and for sentences answered incorrectly are also provided in Table 1. These times were analysed using a 2 (Memory for Meaning: Correct or Incorrect) \times 2 (Sentence Type: Important or Unimportant) within participants ANOVA.

Total gaze time was longer for sentences that were answered correctly than for sentences that were answered incorrectly, $F(1, 27) = 17.25$, $p < .001$, $\eta^2_p = .39$. There was also a main effect of sentence type which replicated the analysis reported above that important sentences were read for longer than unimportant sentences, $F(1, 27) = 17.24$, $p < .001$, $\eta^2_p = .39$. The interaction between sentence type and memory for meaning performance was not significant ($F < 1$) indicating that the longer total gaze times for sentences answered correctly applied to both important and unimportant sentences.

The standard deviation of gaze time for important sentences that were answered correctly was noticeably higher than the other standard deviations in Table 1. This appears to reflect a tendency for participants to sometimes dwell for a relatively long period of time on important material. This is consistent with a satisficing account of skim-reading. Statistical outliers did not cause the high variance – only one data point was greater than 2 standard deviations from the mean and removing this value did not affect the pattern of statistical significance.

The results presented above indicate that participants were successful at allocating their time to more important parts of the text and that this aided their memory for the meaning of important sentences from the text. We now turn our attention to the question of *how* participants managed to focus their attention on more important parts of the text. Analysis of the pattern of reading over the course of a paragraph provides a starting point to address this question.

Reading Strategy within a Paragraph

Mean total gaze times per character for all lines from first to eleventh within each paragraph were computed and are shown in Figure 2. As for the previous analyses, where there was an incomplete line at the end of a paragraph, gaze time was only measured for the area containing text. Figure 2 indicates that total gaze time decreased over the course of the paragraph. A one way within participants ANOVA found that this linear decrease over lines within a paragraph was significant, $F(1, 27) = 44.78$, $p < .001$, $\eta^2_p = .62$. Figure 2 indicates that this was a gradual decrease rather than a step function and that for 10 of the 11 lines total gaze time was more than half the total gaze time for the first line. Only 5 paragraphs had more than 10 lines, so we consider the time for the 11th line to be unreliable. The analysis supports and extends the finding from [11] that the first half of a paragraph was read for longer than the second half.

The means for each line in Figure 2 were averaged across all paragraphs that contained the particular line. However, because paragraphs differed in length ($M = 6.95$ lines, $SD = 2.32$), some paragraphs did not contribute data to the later lines. This means that the figure reflects the distance of each line from the start of the paragraph but does not clearly represent the distance of a line from the end of the paragraph. Moreover, it seems plausible that the distance from the end of a paragraph may affect reading time. To account for this each paragraph was divided into 7 equal intervals following a procedure used by [15]. Where there were more than 7 lines some intervals represented the mean of more than one line and where there were fewer than 7 lines some intervals were left empty. All paragraphs contributed a value for the first and last interval. This transformation of the data did not affect the result and there was a linear decrease in total gaze time over the course of the paragraph, $F(1, 27) = 40.76$, $p < .001$, $\eta^2_p = .60$.

The total-gaze-time-per-line data were also used to plot the proportion of times that each line was fixated upon at least once by each participant. These proportions were calculated for every paragraph for each participant and are shown in

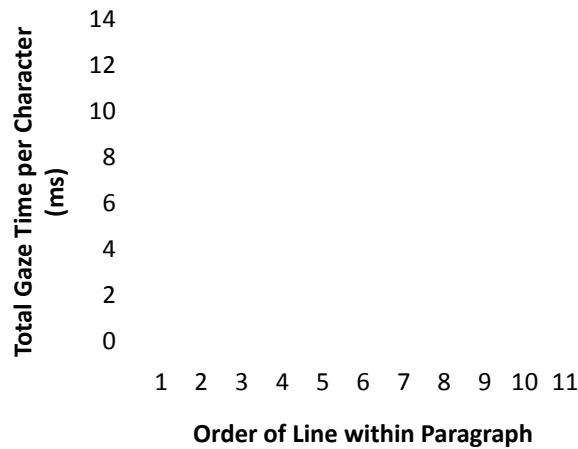


Figure 2. Total gaze time per character for each line within a paragraph.

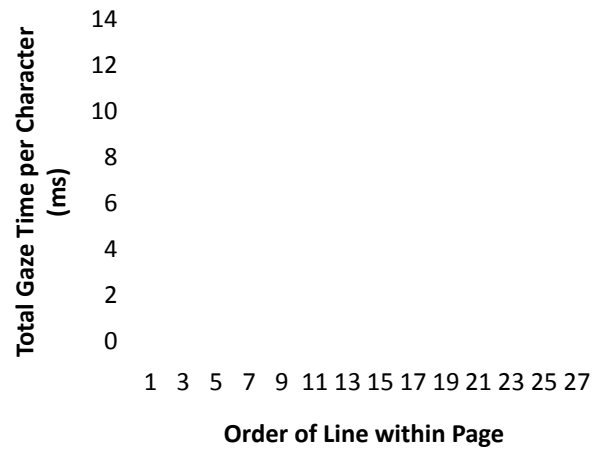


Figure 4. Total gaze time per character for each line within a page.

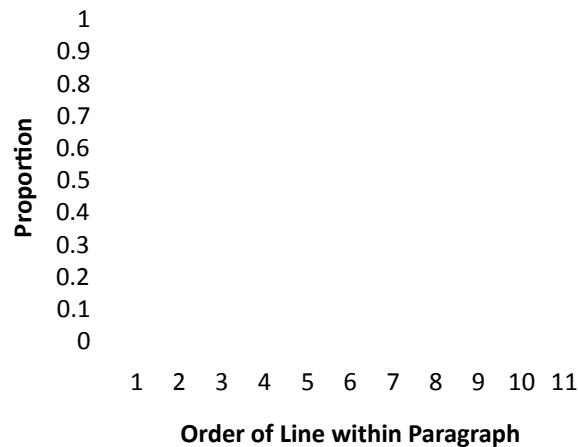


Figure 3. Proportion of times each line in a paragraph was fixated upon at least once by each participant.

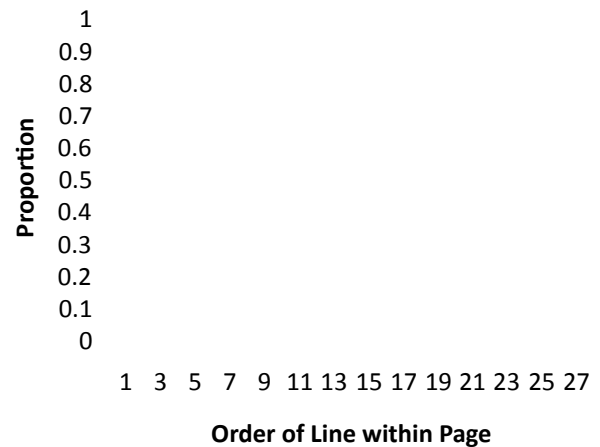


Figure 5. Proportion of times each line in a page was fixated upon at least once by each participant.

Figure 3. The figure shows that lines earlier in the paragraph were more likely to be fixated upon than lines later in the paragraph, $F(1, 27) = 8.20, p = .008, \eta^2_p = .23$. More importantly though, the figure indicates that most lines were fixated upon at least once and, typically, participants did not just read the first line or two of a paragraph. This is consistent with a satisficing strategy where participants read each paragraph and then skip to the next paragraph when the rate of information gain falls below threshold. We next assess the pattern of reading times over the course of a page.

Reading Strategy within a Page

Mean total gaze times for each line within a page are provided in Figure 4. Blank lines between paragraphs were excluded from the figure and analyses. The means in Figure 4 suggest that total gaze time decreased over the course of a page. This effect was reliable when tested using a one way within participants ANOVA, $F(1, 27) = 44.90, p < .001, \eta^2_p = .62$. As for the paragraph analyses, the decrease was gradual rather than a step function. This analysis is consistent with the finding in [11] that paragraphs toward the top of the page are read for longer than paragraphs towards the bottom of the page.

The proportion of times that each line within a page was fixated upon at least once by each participant is given in Figure 5. This figure shows that lines towards the top of the

page were more likely to be fixated upon than lines towards the bottom of the page, $F(1, 27) = 19.62, p < .001, \eta^2_p = .42$. As for the paragraph analyses, the figure also shows a high proportion of lines were fixated upon at least once. The gradual decrease over the course of a page indicates that, in addition to the paragraph, participants may have treated the page as a unit of text over which they satisfice.

Gaze times were also analysed according to their position across the page. The page was divided into ten equal-width stripes and total gaze time for each stripe was measured. Only areas of the screen containing text were included and times were calculated per tenth of a line of text. Figure 6 shows total gaze times for each stripe (tenth of the screen) in order from left to right. Time spent looking in each stripe was approximately equal except for the first stripe which had a slightly longer total gaze time and the final tenth which had a much shorter total gaze time. The decrease in total gaze time from left to right was significant, $F(1, 27) = 97.58, p < .001, \eta^2_p = .78$. The higher total gaze time for the

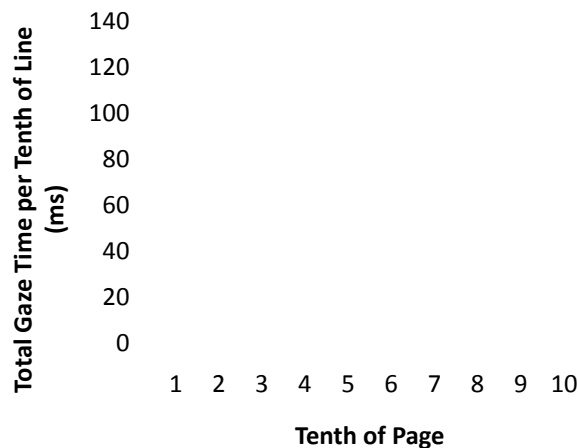


Figure 6. Total gaze time for each tenth of a page divided into equal-width vertical stripes across the width of the page. Tenths are ordered from left to right and reported as tenths of a line.

leftmost tenth of the page is consistent with a pattern of scanning down the left hand side of the text; however, the size of the difference is not large. The result for the final tenth is attributable to the text not being justified to the right margin of the page – this meant the text finished a number of characters before the end of most lines.

DISCUSSION

Overall, the results suggest that skim-readers can successfully focus on important text and that they achieve this by satisficing. Eye tracking analyses indicated that sentences, lines and paragraphs containing important information were read for longer than sentences, lines and paragraphs containing unimportant information. Furthermore, these differences improved readers'

understanding, as better memory for the meaning of a sentence was associated with longer reading time for that sentence. The results enable us to discount the idea that the benefits for skimming reported by [11] were due to simply reading a more distributed selection of text. Skim readers' strategies were more sophisticated than that – they read important text and skipped over unimportant text.

Support was also found for the use of satisficing as a strategy to help readers focus upon the most important text. Average reading time for each line decreased gradually over the course of a paragraph, as did the proportion of times a line was fixated upon at least once. Therefore, lines toward the end of a paragraph were more likely to be skipped over than lines towards the start of a paragraph. This is consistent with a satisficing account that states skimmers begin every paragraph and continue reading until the rate of information gain drops below a threshold whereupon they skip to the beginning of the next paragraph.

Satisficing also provides an explanation for the rather smooth rate of decrease in reading time over the course of a paragraph. If important information is distributed equally throughout a paragraph, then the rate of information gain is equally likely to fall below threshold at any point and the probability that a participant has skipped to the next paragraph will increase at a consistent rate throughout the paragraph. Results also showed that almost all lines were read for at least half as long as the first line and the proportion of times a line in a paragraph was fixated upon at least once was always 0.4 or greater, suggesting that many paragraphs were read in their entirety. Assuming the threshold at which participants leave a paragraph was not too easily attainable this is, again, consistent with satisficing behaviour.

The reading times for each line within a page decreased over the course of the page. This suggests that participants also evaluated pages when satisficing and may have monitored rate of information gain within both areas of text while reading. That is, readers may simultaneously assess whether useful information is provided within the current page overall and also within the particular paragraph being read. Because paragraphs started and finished throughout a page it is difficult to be clear about reading patterns just due to the page. As well as generally adding variance to the page level analyses a tendency to skip information towards the end of paragraphs could also be partly responsible for the decrease in reading time over the course of the page. However, [11] simultaneously analysed within and between paragraph effects. They found that paragraphs towards the top of a page were more likely to be read for longer and that differences in reading times between the first and second halves of a paragraph could not be explained by the position of the paragraph on the page. Therefore, the most likely explanation for the data is that readers evaluate both the page and the paragraph when satisficing.

The relatively high reading times for lines late in a paragraph and a page suggests some or all pages of text were not read in an F-shape such as that suggested by [22]. It seems unlikely that a horizontal movement across the start of the paragraph would incorporate information 11 lines from the start of the paragraph. The results for reading times across the width of the screen provided limited support for a scanning pattern down the left hand side of the screen. Reading time for the vertical stripe that was the leftmost tenth of the screen was marginally higher than for the rest of the screen. This difference was not large though and could be easily caused by corrections to eye movements after the relatively long traversal between words at the end of one line and the start of the next [27]. Finally, the reading times for each line within a page showed that text towards the end of a page was often read. We do not interpret these results as strong evidence against a general tendency to read in an F-shape. The pattern was observed by Nielsen under reading conditions that differed in many ways from those in our study and below we discuss the importance of some of these factors. Nonetheless, for the specific set of constraints within our experimental paradigm, satisficing provided a better account of the data.

Applicability to the Web

The texts and target sentences used in this experiment were carefully selected and matched to enable the study of skimming versus reading at normal speed and the processing of important versus unimportant information. The alternative method of allowing readers to browse the Web freely is confounded by the amount of text on a page, the density of important information, the quality of the writing, the structure of the page and the location of information within it, the presence of graphics and other multimedia, the intrusive effect of adverts, the number and type of links from a page etc., and this is before considering factors pertaining to the user and the task. Therefore, as a first step, we believe the control in our design was necessary to focus on the behaviour of interest – skim-reading. Notwithstanding this, key features of our method are representative of reading situations on the Web and were designed to promote similar reading behaviours. For example, participants were allowed to freely navigate through a number of pages of text that were linked together and the task was simply “To learn as much as possible in the time available”. Naturally, the next step is to attempt to generalize our findings to other reading materials and task constraints. With a view to this future research, we shall now discuss factors of particular relevance to reading on the Web.

In our study, participants had more than twice the amount of text than they could read in the time available. This proved sufficient to discriminate between skimming and reading at normal pace but arguably is less extreme than typical reading conditions on the Web. The sheer size of the Web means there can be a near limitless supply of text and there is always the option of continuing to search for more

text. Moreover, quality and type of text was relatively constant in our experiment whereas text on the Web comes from a variety of different sources and, despite the efficiency of search engines, can be of limited relevance [13]. Thus, skimming online may be different from the skimming observed here due to a different ratio of time to text and higher variance in the quality of text. Studies of Web usage support this argument, as page visits are often very short indeed [6,7,32]. For example, Weinreich, *et al.* [32] report that 25% of all pages were displayed for less than 4 seconds, and 52% of all visits were shorter than 10 seconds. However, they also found that 10% of all page visits were longer than 2 minutes. This suggests that Web users engage in some rapid evaluative behaviour not observed in our study but it also implies that less cursory reading, potentially including satisficing, was also common. Indeed, although these longer visits were fewer in number they accounted for a high proportion of the total time users spent on the Web.

The frequency of rapid visits to Web pages suggests that users may be engaging in some form of “sampling” behaviour that acts as a precursor to satisficing or normal reading ([28]; see also research on “document triage”, e.g., [2,3,8]). Sampling involves reading a small part of a document and using that to evaluate its content before reading further. Typically, users might be expected to sample a number of different documents before deciding upon one to read but, in principle, users could evaluate each individual sample against a pre-existing baseline and make an immediate decision. Sampling will be more efficient when there is high variance in quality between the available texts – as is often the case on the Web. The scanning of pages in an F-shape, as described by Nielsen, may be one such sampling behaviour and the absence of sampling in our experiments could explain the absence of an F-shaped reading pattern.

From an applied point of view, we believe that both satisficing and sampling are important. Website designers need to capture users’ attention relatively quickly during the sampling phase to prevent them leaving and sampling an alternative site. However, it is the users that stay for the longest periods of time that are likely to be the most important visitors to a site, and our research indicates that when navigating within fairly homogenous pages, such as those found within the same Website, users are more likely to satisfice than sample.

The high proportion of rapid visits reported by Weinreich *et al.* may be in part a reflection of the type of pages visited in that study. Unconstrained use of the Web entails visiting pages, such as homepages and lists of content, that are simply navigated through to reach more useful content. It also seems plausible that, unlike the text in this study, such pages may be read in an F-shape [20]. The materials used in this study were not designed to encourage such reading behaviour. Although such rapid visits are frequent it does not follow that they are correspondingly important for an

understanding of skimming behaviour. We seek to understand how skimming allows gains in information. Focusing on text that has some relation to the user's goal has enabled us to study how readers allocate their time to the most important text within a generally relevant document.

Implications for Design

This discussion and the results from our study suggest several conclusions about skim reading that have relevance for producers of text on the Web.

Locating information at the start of paragraphs and pages increases the likelihood that it will be read. Therefore, writers should ensure that information early in a page should grab and hold the reader's attention. This is the most straightforward conclusion and is not new, following on from general guidelines for writing [31] and specific advice for writing on the Web [21]. Our contribution is to provide supporting data using a controlled experiment and a theoretical account of how this pattern of reading comes about.

Information that is later in a text is still relevant to time-pressured readers. Figures 2-5 indicate that information towards the ends of paragraphs and pages was read by a significant proportion of participants. Writers should not be afraid of including important information after the first line or two provided the preceding text is likely to sustain the reader's attention. Clearly, this will depend on the purpose of the text but the writer's goal need not be to frontload the text with all the major points. Beyond an initial sampling phase readers will satisfice and general principles of writing such as maintaining coherence and explaining causal relations are important to support the comprehension of the text [17].

Readers simultaneously evaluate the current paragraph and the current page. Readers appear to evaluate different sized units of text when deciding whether to keep reading or not. Therefore, writers must anticipate the units of text most relevant to the particular circumstances and structure their text accordingly. This could include inserting section headings and altering the length of paragraphs and/or pages to ensure that if readers do move to the next unit of text, information that is important to the writer is not skipped over.

Skimming can be effective. Although less effective than reading at normal pace [5,12,18], skimmed text can still be understood and remembered. In particular, when satisficing the sections of text that people choose to read may be read for the same amount of time and understood as well as when read without time pressure. This means that complex information can be included within text online and that this information may well be recalled and used at a later date.

Related Work and Future Directions

Finding information on the Web is, of course, not just a question of deciding whether to continue reading text or

not. Both search and navigation online have been extensively investigated [e.g. 10,16,24] and a full account of their relationship to skim reading is beyond the scope of this article. Nonetheless, another experiment in [11] provided some insight into the importance of the links between pages. They arranged pages of text in a hierarchical Website-like structure and varied the links between pages to manipulate the ease with which participants could navigate through the text. Subsequent tests of text understanding found the advantage for skimming over reading at normal speed was dependent on the ease with which readers could navigate between pages.

Work investigating the links to a page of text highlights another issue not touched on here – the depth of understanding achieved by skim reading. Requiring users to click on a link to access a page of instructional text can increase the amount read each time the text is accessed and the subsequent level of understanding achieved [9]. Similarly, [29] demonstrated that the different strategies adopted by readers of hypertext did not affect their understanding of features of the text, but did affect their deeper understanding of the meaning of the text. We have shown that skimming is an effective method for quickly grasping the most important points of a text but writing text that exclusively supports rapid reading may marginalise the more sophisticated processes present in slower reading. Just such a phenomenon has already been anecdotally observed elsewhere [4,25].

Finally, we note that a measure of readers' perceptions of their progress while reading would help understand the decisions taken by readers on the Web. The theory of satisficing supposes, after information foraging [24], that behaviour is moderated by rate of information gain but currently it is difficult to measure this rate. It is possible to answer similar questions about currency-dependent foraging by investigating tasks in which the currency is more readily available [14,23], and thus to test particular heuristics underlying local decisions to switch from one activity to another. But for understanding skim reading *per se*, this rather sidesteps the issue. It remains for future work to investigate whether any indirect measures of information gain (e.g. subjective reports) allow similarly sophisticated analysis of the local satisficing decision to stop reading and skip to the next unit of text.

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